SUSY Higgs in ττ and ττb final states and φb combination at DØ

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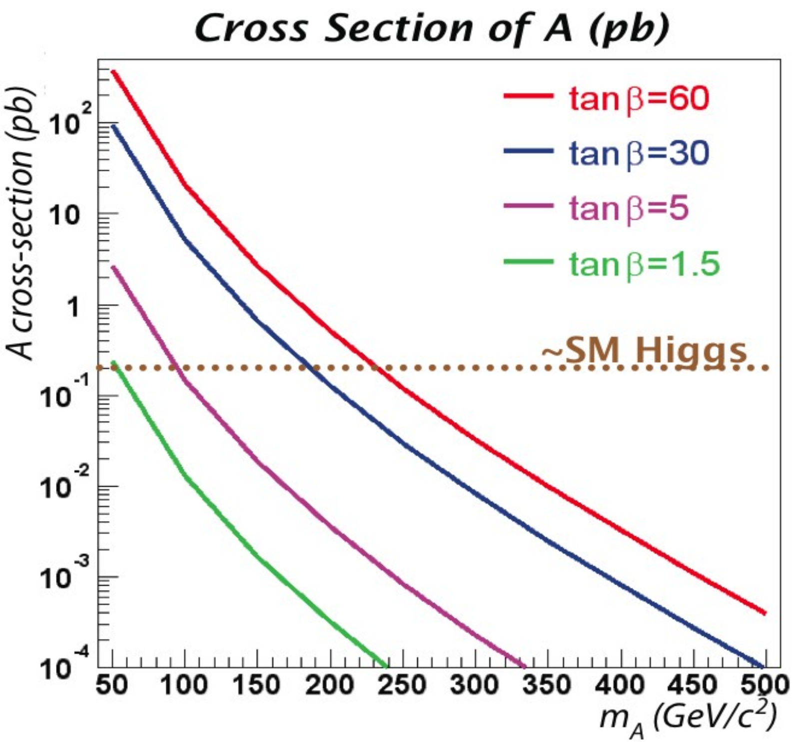
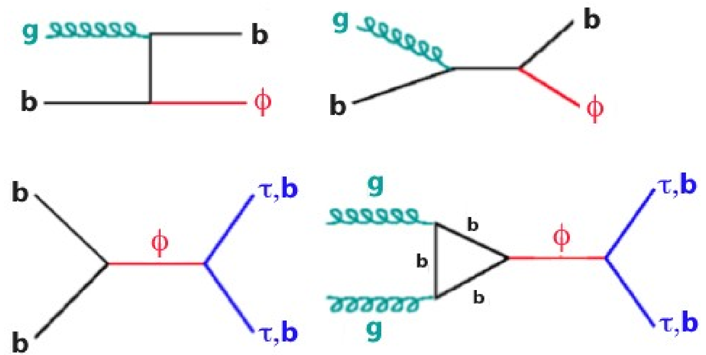
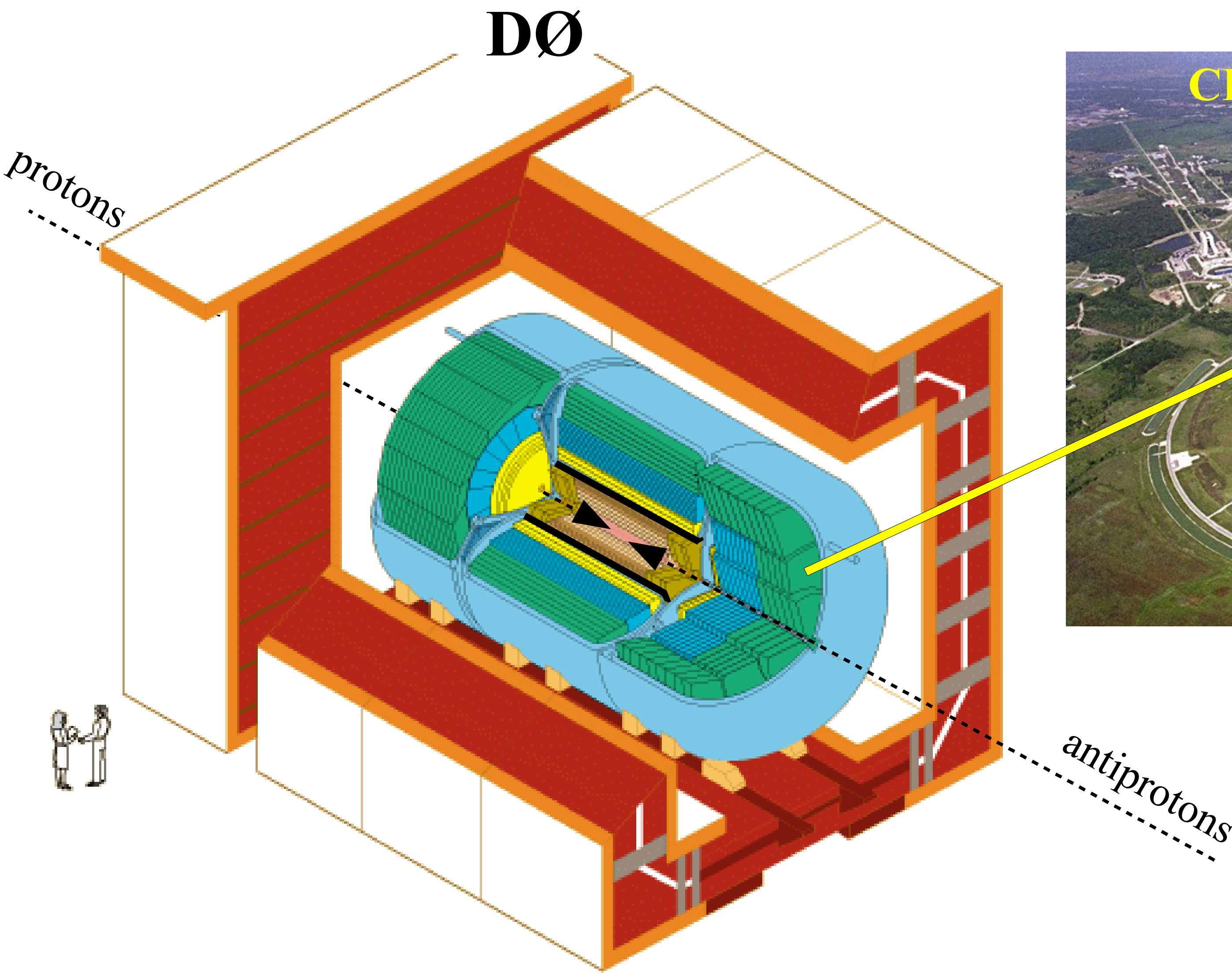
MSSM Higgs

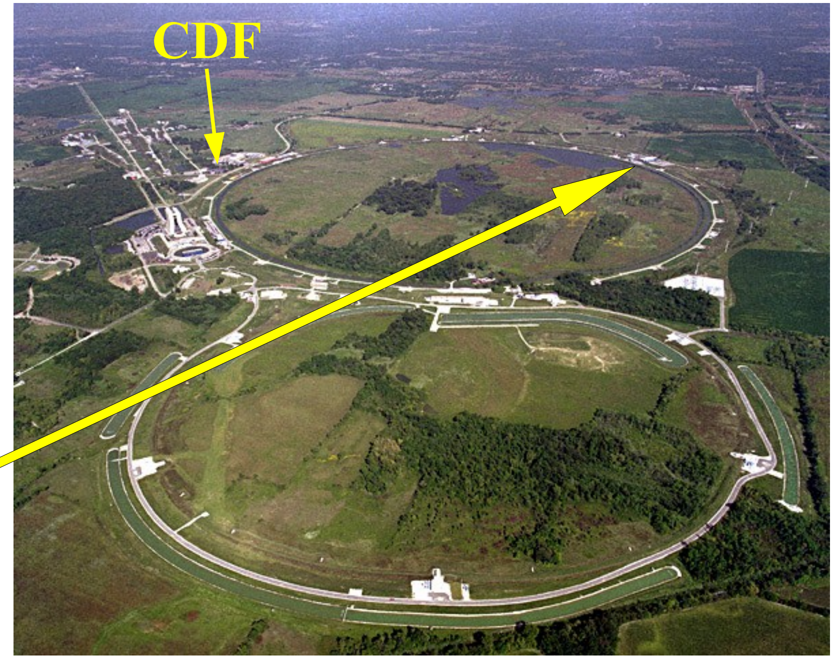
- MSSM requires 2 Higgs doublets
  - $\Rightarrow$ 5 Higgs: $\underbrace{h^0, H^0, A^0}_{\varphi}$, and $H^\pm$
  - At tree-level, MSSM Higgs fully specified by two parameters
    - m_A = mass of CP-odd Higgs
    - $\tan\beta = \langle H_u \rangle / \langle H_d \rangle$ (ratio of v.e.v.'s)
    - Radiative corrections introduce dependence on additional SUSY parameters
  - Enhanced coupling to down-type fermions by $\sim 2\times\tan^2\beta$
    - Enhanced φ and φb production
    - Decay ~100% to bb and $\tau\tau$
      - $BR(\varphi \to b\bar{b}) \approx 0.9$
      - $BR(\varphi \to \tau\tau) \approx 0.1$





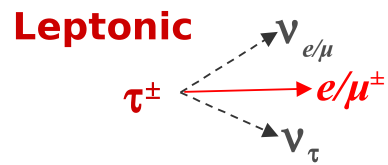
DØ Detector



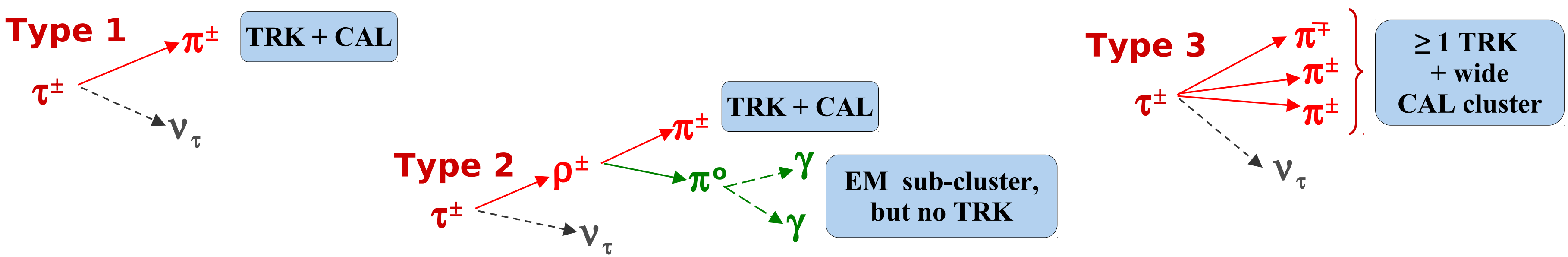


τ Identification

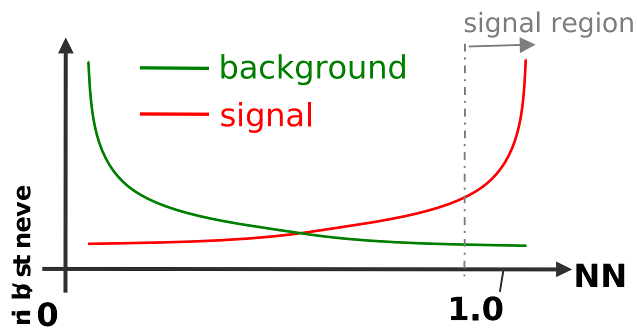
- Leptonic decays: τ_e, τ_μ
  - Identify isolated electron or muon:



- Hadronic decays: τ_{had}
  - Separate into 3 categories defined by the decay mode:

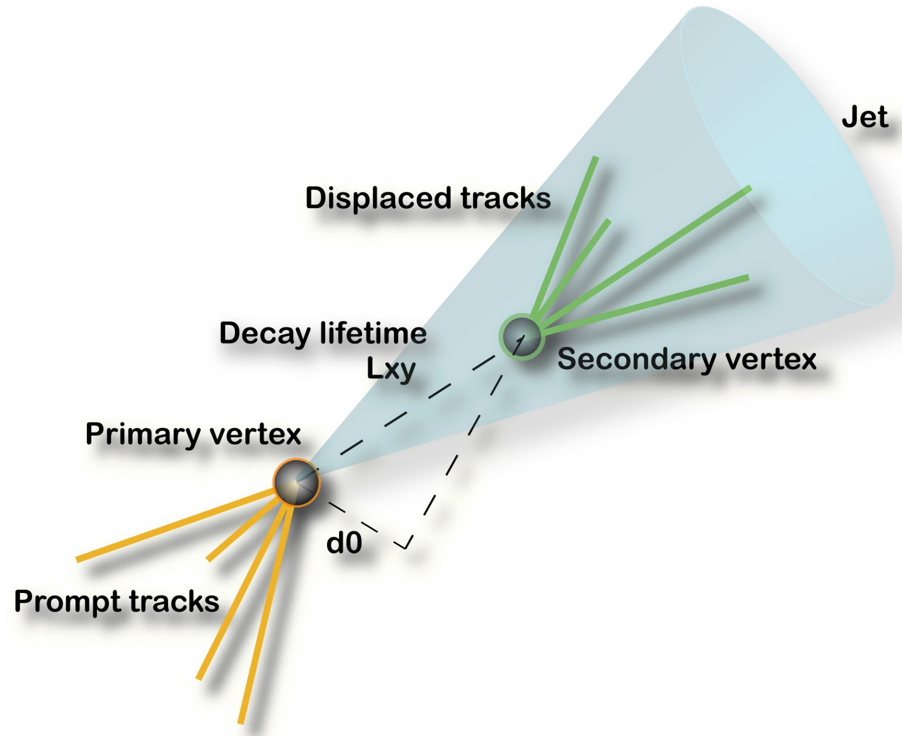


  - Use Neural Network (NN) to discriminate each type from jet background
    - Efficiency ≈ 65%
    - Fake rate ≈ 2%



b-jet Identification

- b-quark ⇒ b-hadron ⇒ decay
  - May travel a few mm before decaying ⇒ Displaced secondary vertex
- Background has mostly "light jets" from gluons or light quarks
  - W/Z+jets is less than 5% W/Z+$b\bar{b}$
- Identify jets that are likely to have a secondary vertex due to a B decay
  - 50% - 70% efficiency for real b jets
  - 0.5% - 5% fake rate for light jets



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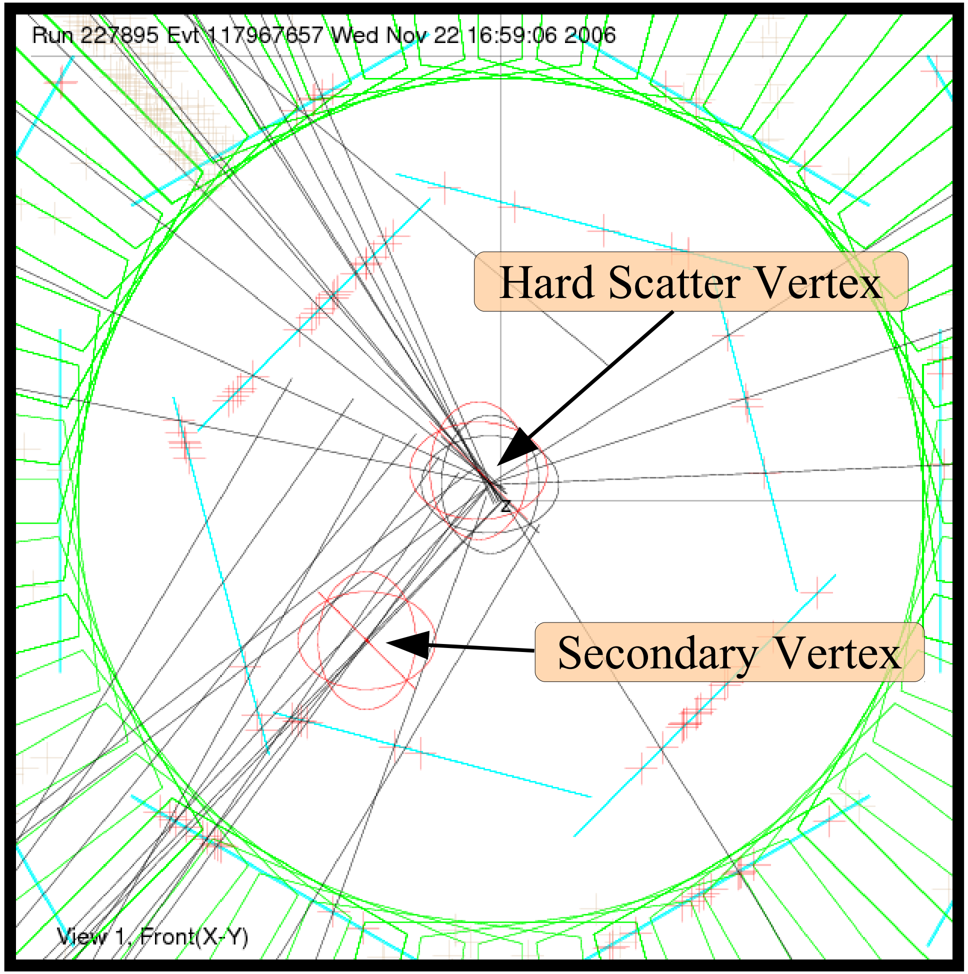


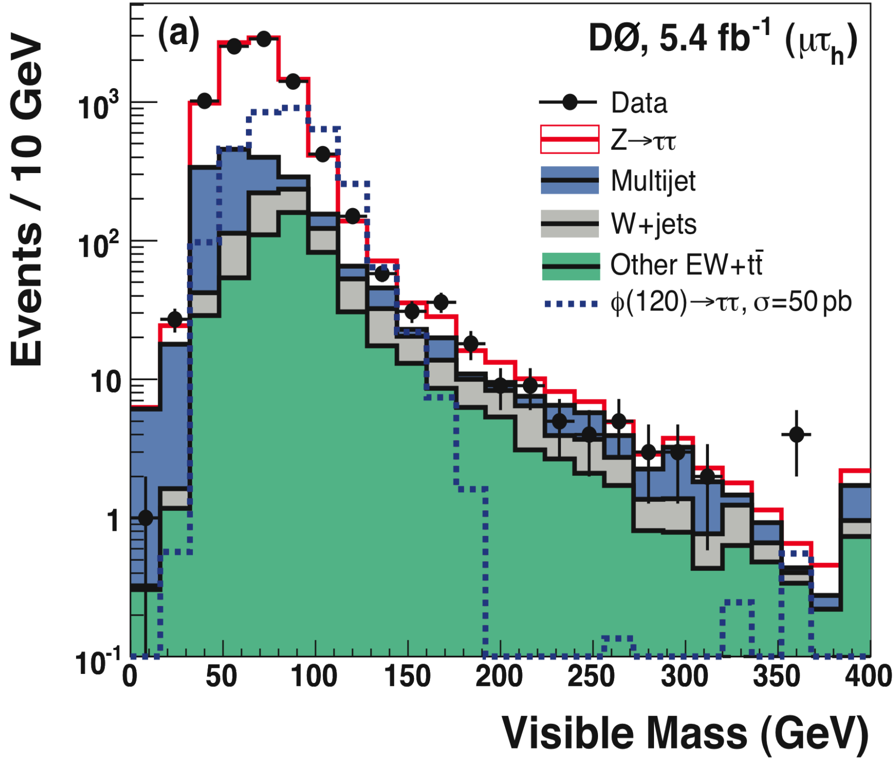
Inclusive $\varphi \rightarrow \tau\tau$: Search

Submitted to PLB, arXiv:1106.4555 [hep-ex]

- $5.4\ \text{fb}^{-1}$ of data
  ~5 × more than previous result: PRL 101, 071804 (2008)
  - $\tau_e \tau_\mu \Rightarrow$ oppositely charged electron and muon
  - $\tau_\mu \tau_{had} \Rightarrow$ oppositely charged muon and τ_{had} candidate
  - Reduce W+jet background with cut on $m_T < 50$ GeV
- Use visible mass to test for presence of signal

$$M_{vis} = \sqrt{\left(P_{\tau_1} + P_{\tau_2} + \not{P}_T\right)^2}$$

  - Data consistent with background ⇒ Set limits



Inclusive $\varphi \rightarrow \tau\tau$: Results

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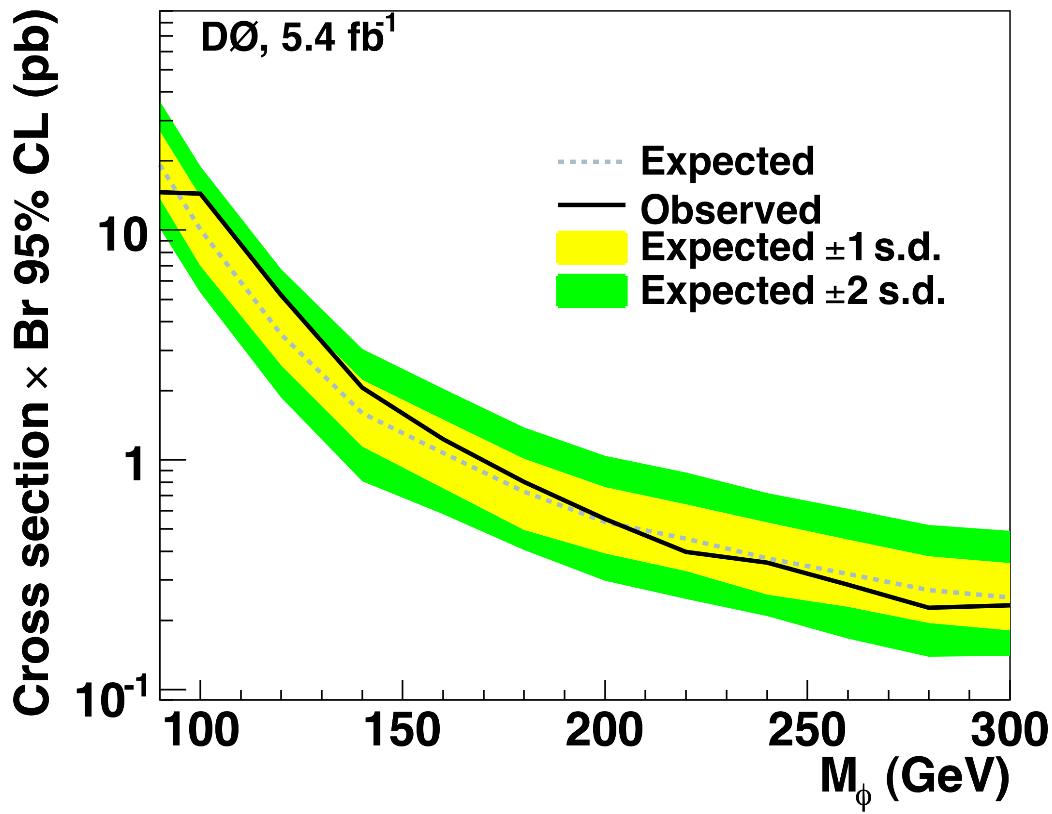
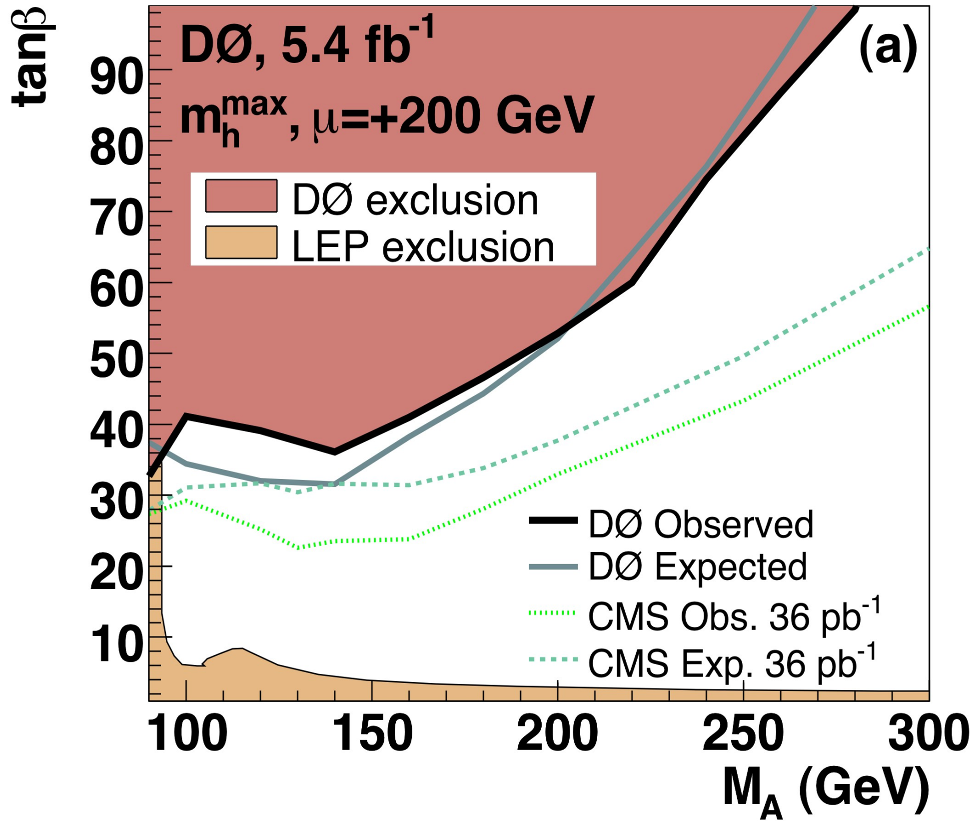
- Set model-independent limit on $\sigma \times BR$
  - Assume only that width of M_φ is small compared to resolution



Inclusive $\varphi \rightarrow \tau\tau$: MSSM Results

Submitted to PLB, arXiv:1106.4555 [hep-ex]

- Set model-independent limit on $\sigma \times BR$
  - Assume only that width of M_φ is small compared to resolution
- Translate into representative MSSM scenarios
  - m_h^{max} and no-mixing, $\mu = \pm 200$ GeV
    - FeynHiggs v2.8.1
  - Expect sensitivity of tan $\beta \approx 30$ for low m_A ($\approx$140 GeV)
  - Comparable to recent 36 fb^{-1} limits from CMS and ATLAS

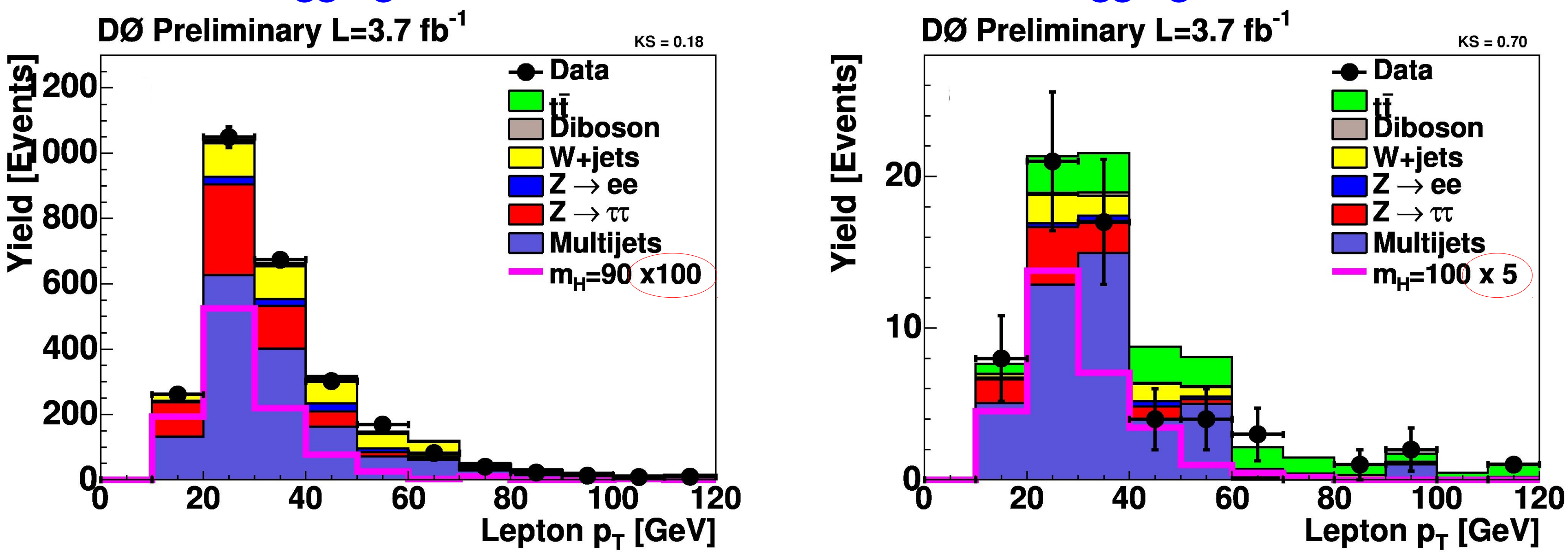


$\varphi b \to \tau_e \tau_{had} b$: Search

Conference Note D0 Note 5974-CONF

- 3.7 fb^{-1} of data
  - Complimentary to $\varphi \to \tau\tau$ and $\varphi b \to b\bar{b}b$
    - b-jet ⇒ much less $Z \to \tau\tau$ background than $\varphi \to \tau\tau$
    - τ ⇒ much less multijet background than $\varphi b \to b\bar{b}b$

Before b-tagging: After b-tagging:



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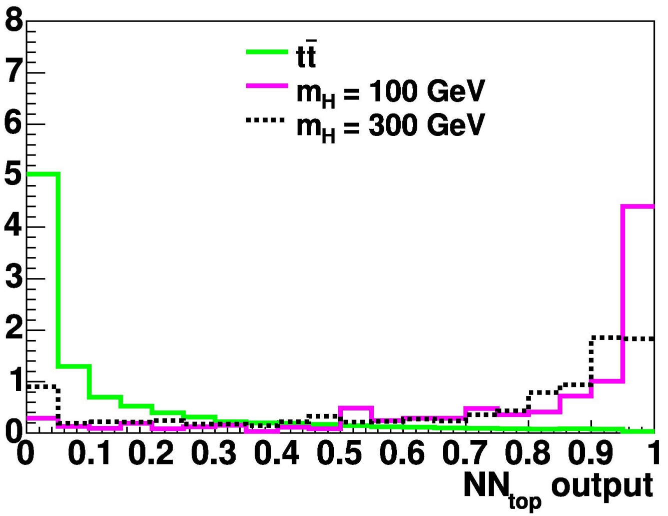
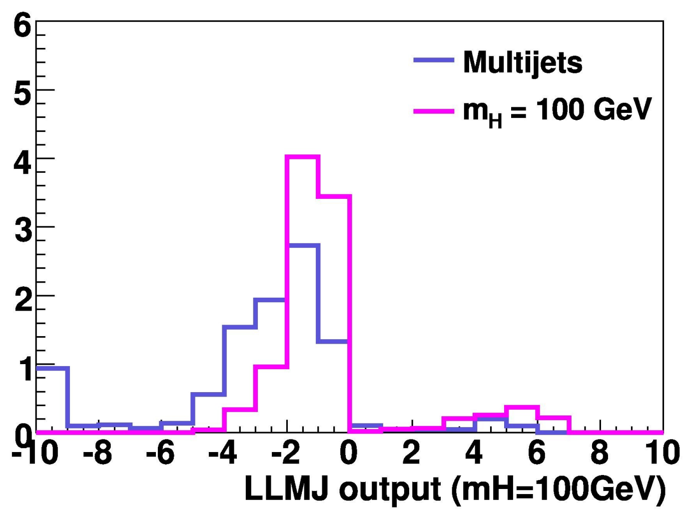
  - Multivariate discriminants for separating tt and multijet backgrounds





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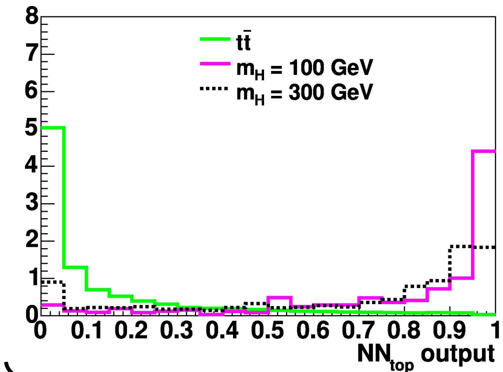
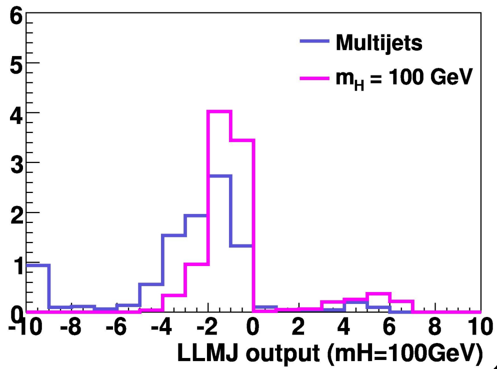
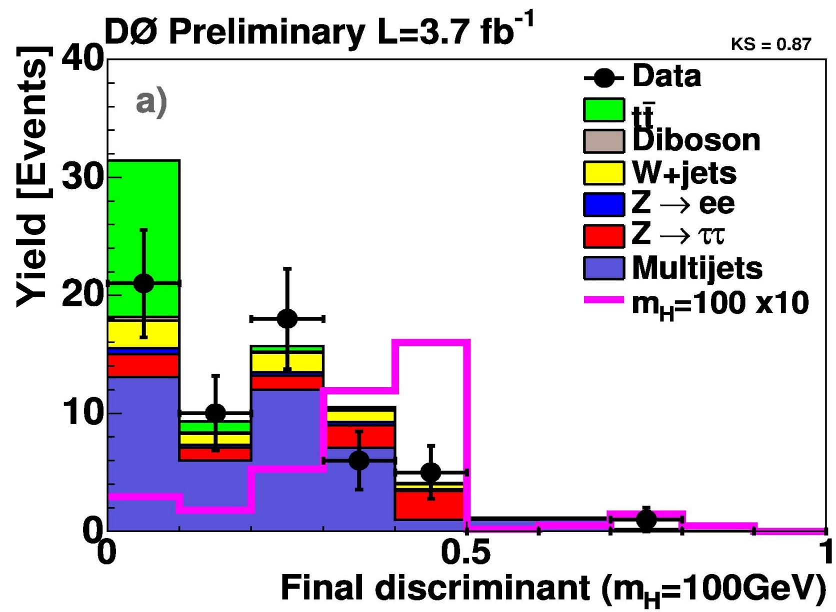






- Combined to form final discriminant

$\varphi b \rightarrow \tau_\mu \tau_{had} b$: Search

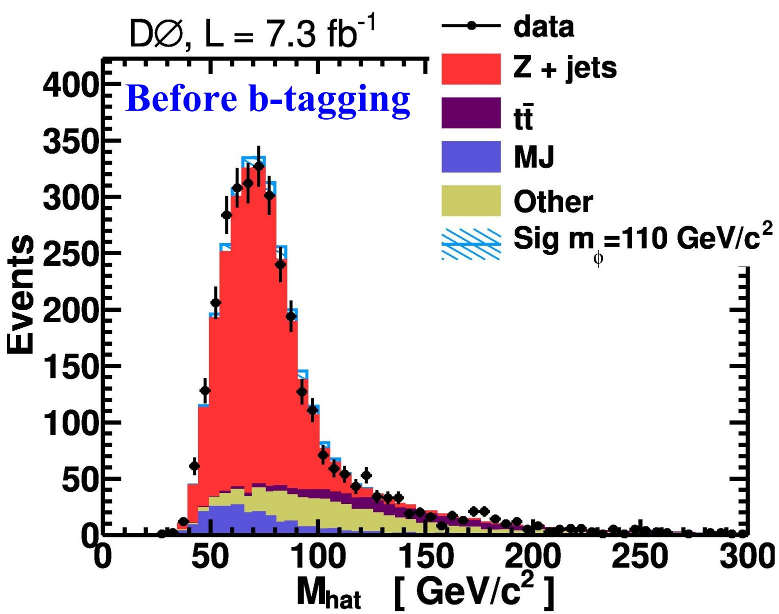
Submitted to PRL, arXiv:1106.4885 [hep-ex]

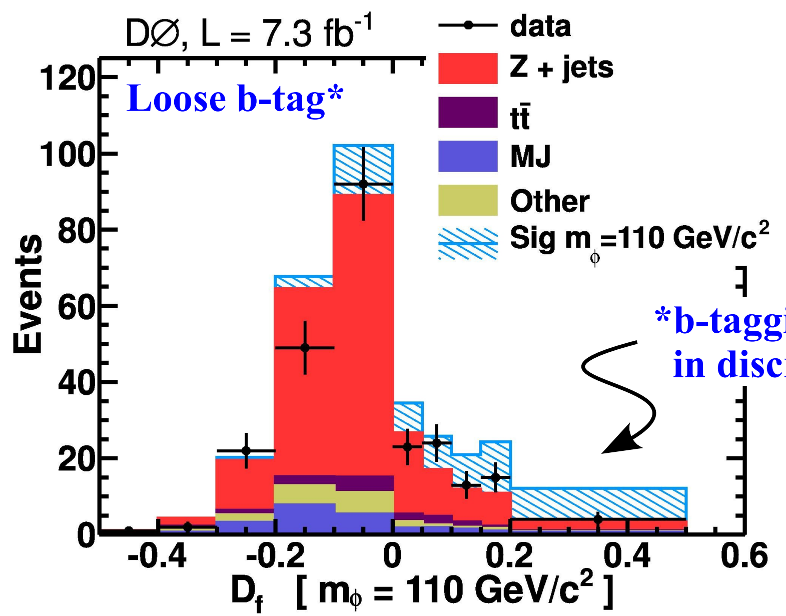
- 7.3 fb^{-1} of data

  Supersedes previous 2.7 fb^{-1} publication: PRL 104, 151801 (2010)

  - Improved sensitivity
    - Inclusive trigger: single muon, muon+jet, tau+jet, missing energy+jet triggers
    - Final likelihood formed from four individual discriminants: D_{top}, D_{MJ}, NN_b, M_{hat}

$$M_{\mathrm{hat}} \equiv \sqrt{\left(E^{\mu\tau_h} - p_z^{\mu\tau_h} + \not{E}_T\right)^2 - |\vec{p}_T^{\,\tau_h} + \vec{p}_T^{\,\mu} + \vec{\not{E}}_T|^2}$$





*b-tagging NN used in discriminant

$\varphi b \rightarrow \tau\tau b$: Results

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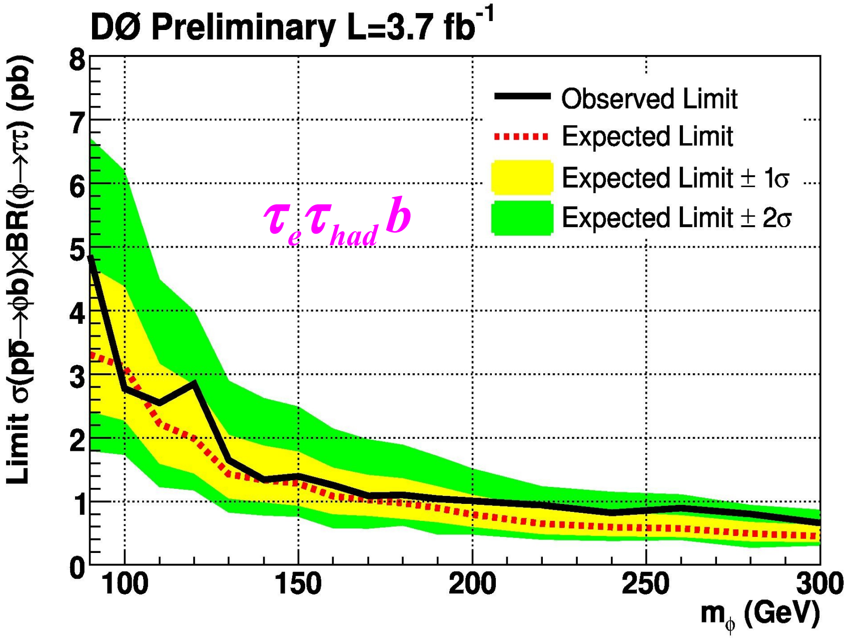
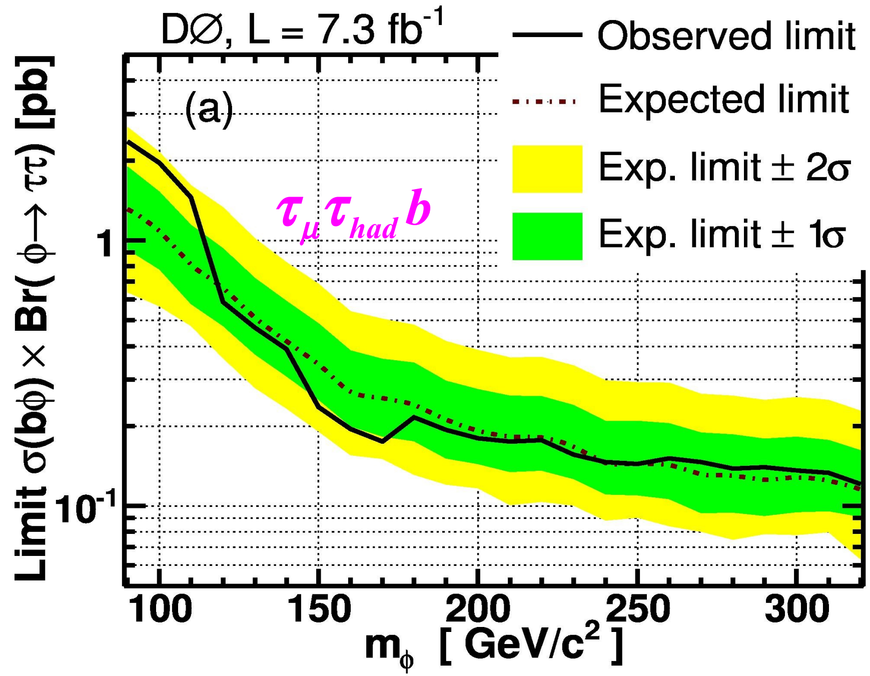
Conference Note D0 Note 5974-CONF

- Observe no significant excess over backgrounds
  - Set model-independent limits on σ×BR





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- Observe no significant excess over backgrounds
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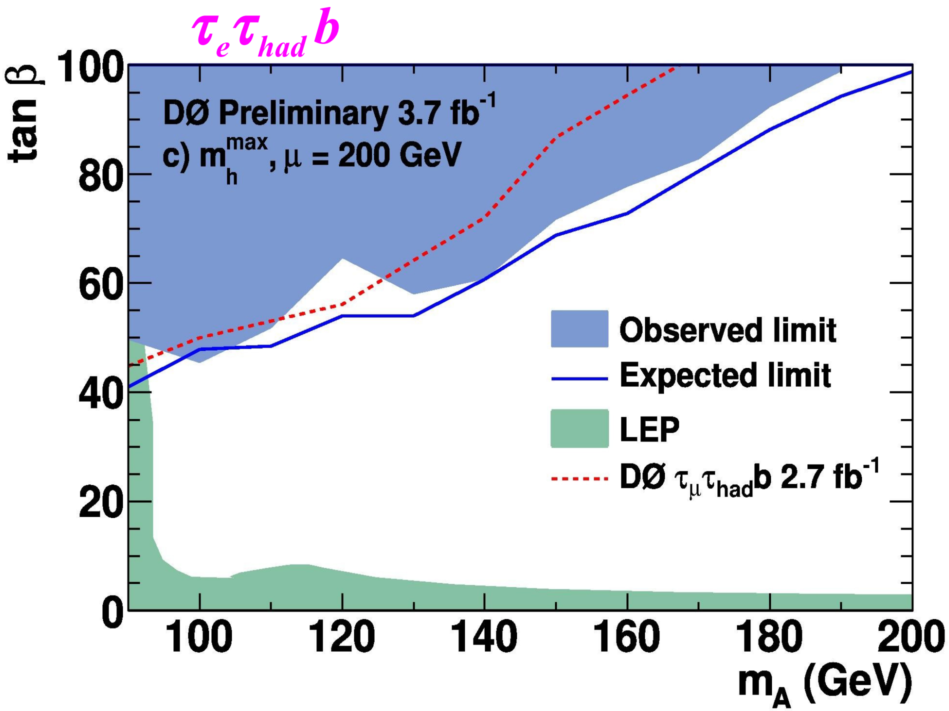
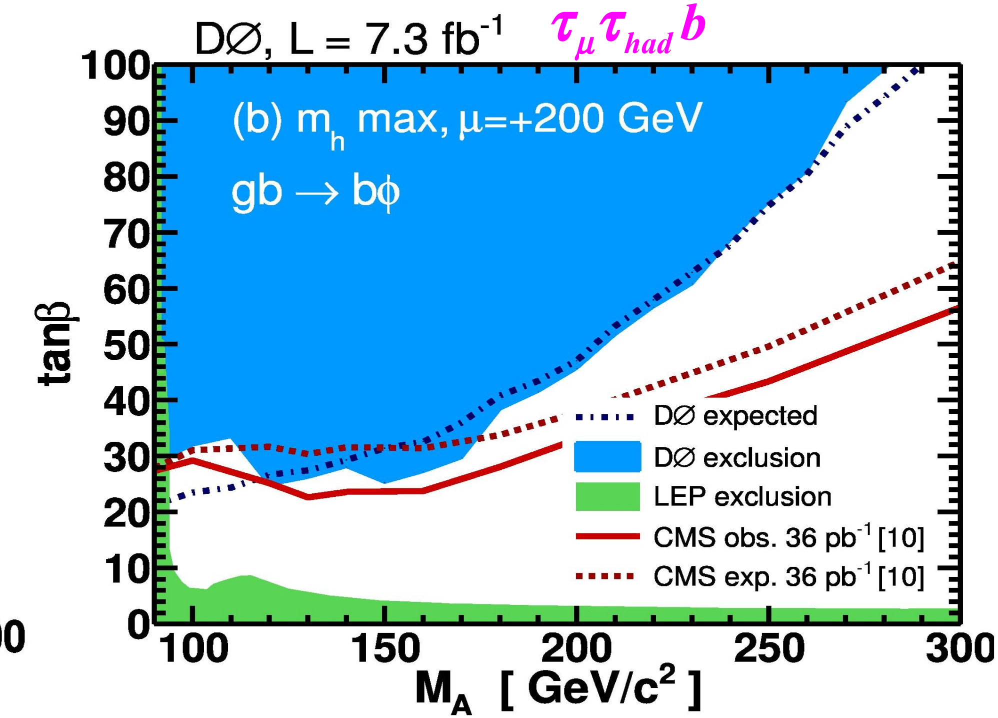
  - Translate to MSSM exclusion in $M_A \times \tan\beta$ plane





φb: Combination

Conference Note D0 Note 6227-CONF

- DØ combination of associated φb production
  - $\varphi b \rightarrow \tau_\mu \tau_{had} b$ with 7.3 fb^{-1}
  - $\varphi b \rightarrow bbb$ with 5.2 fb^{-1} (See previous talk by Tom Wright)

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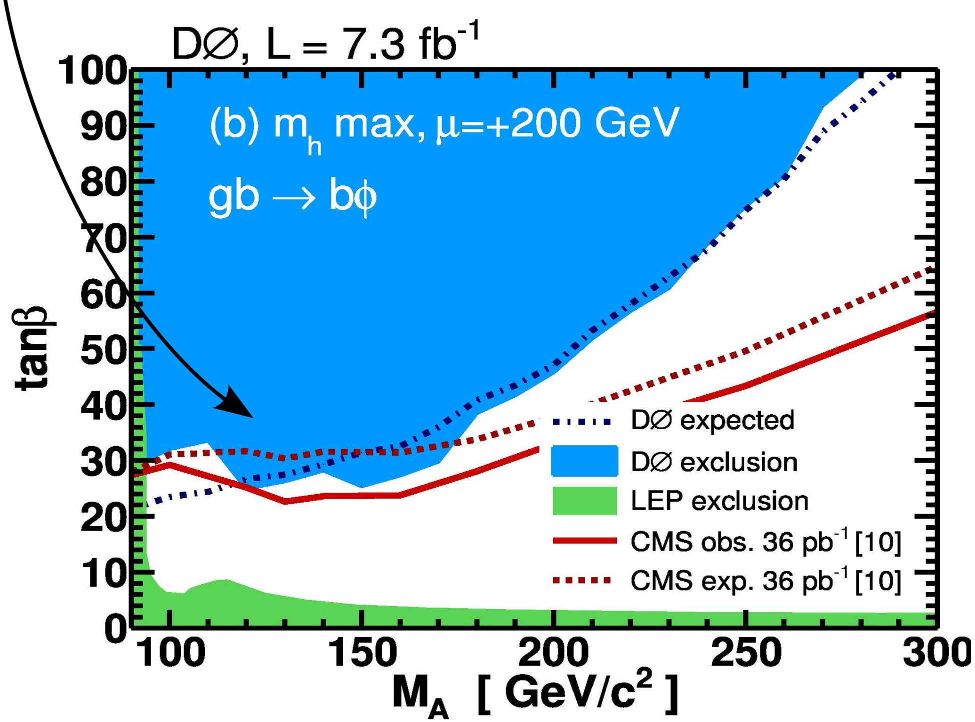

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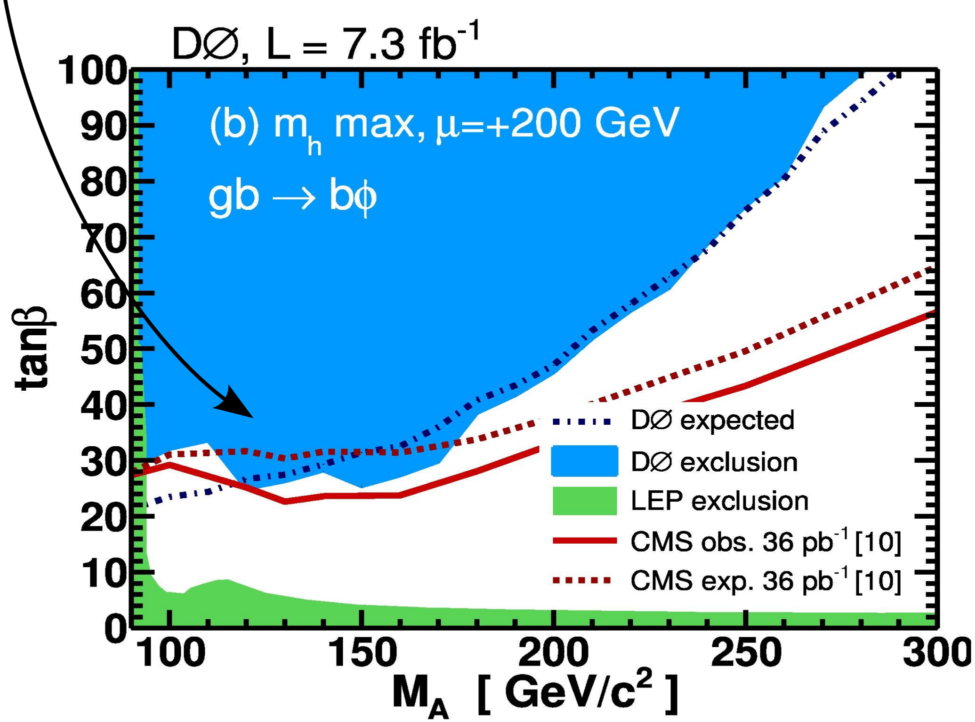
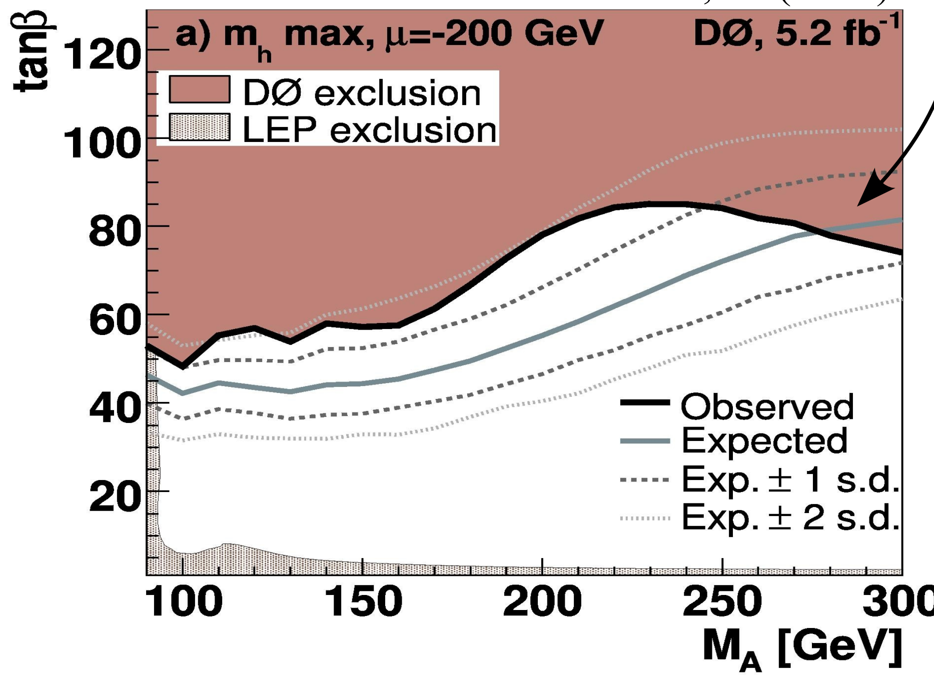


PLB 698, 97 (2011)



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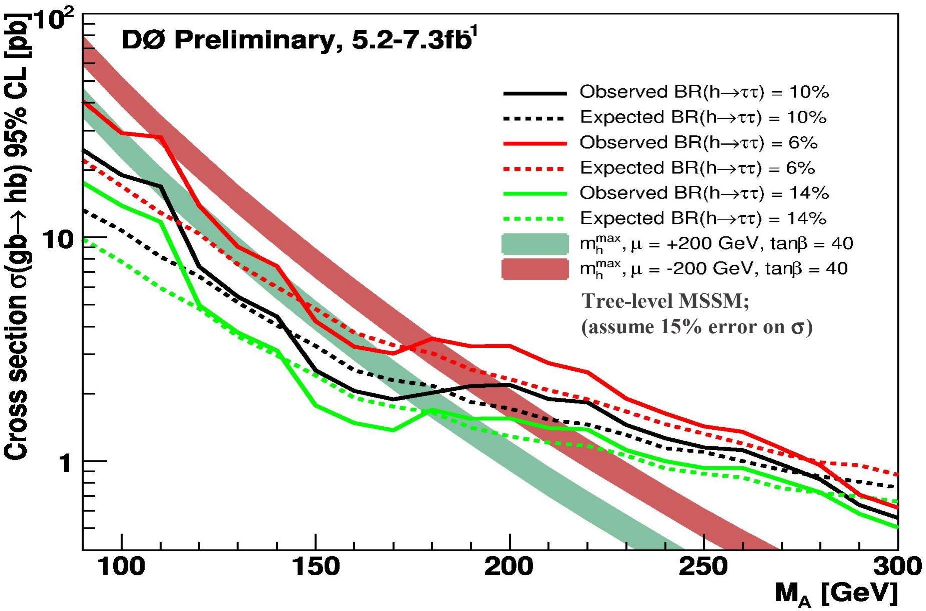
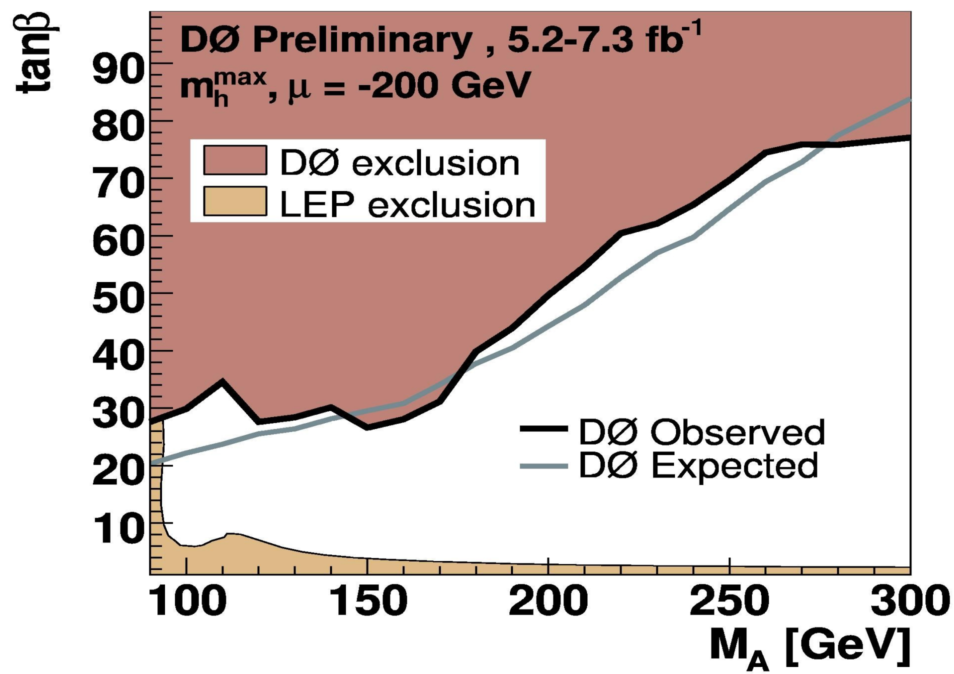
  - $\varphi b \to \tau_\mu \tau_{had} b$ with 7.3 fb^{-1}
  - $\varphi b \to bbb$ with 5.2 fb^{-1} (See previous talk by Tom Wright)
  - Correlate uncertainties: b-tag efficiency and jet modeling
- Limits on $\sigma(gb \to \varphi b)$: Assume narrow Higgs and sum rule: $BR(\varphi \to \tau\tau) + BR(\varphi \to bb) = 1$
- Translate to $M_A \times \tan\beta$ plane

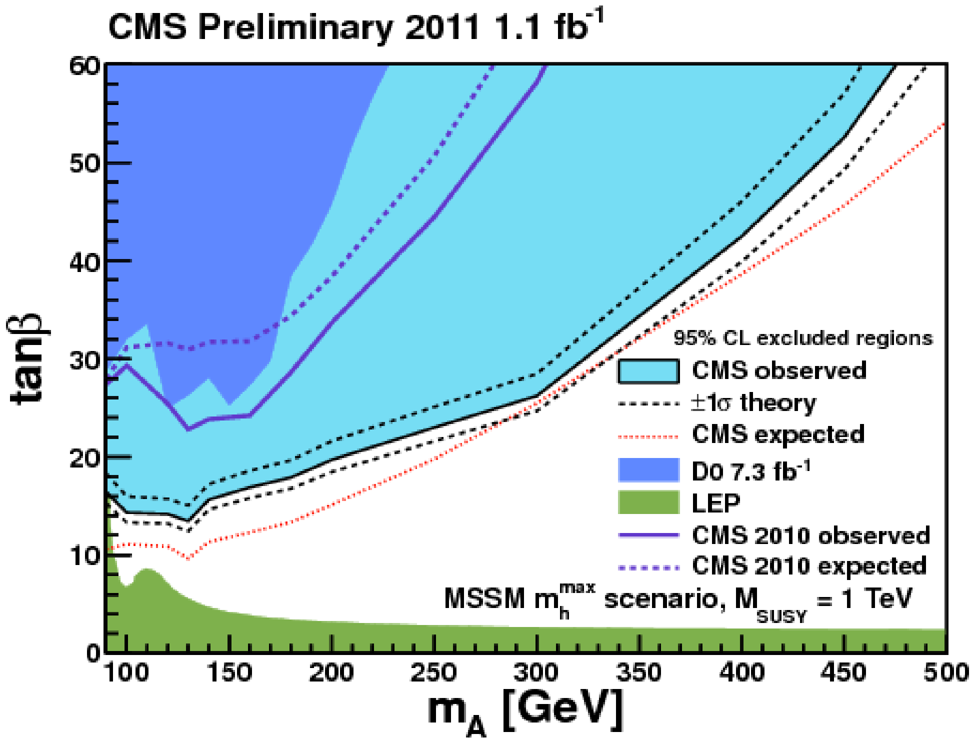




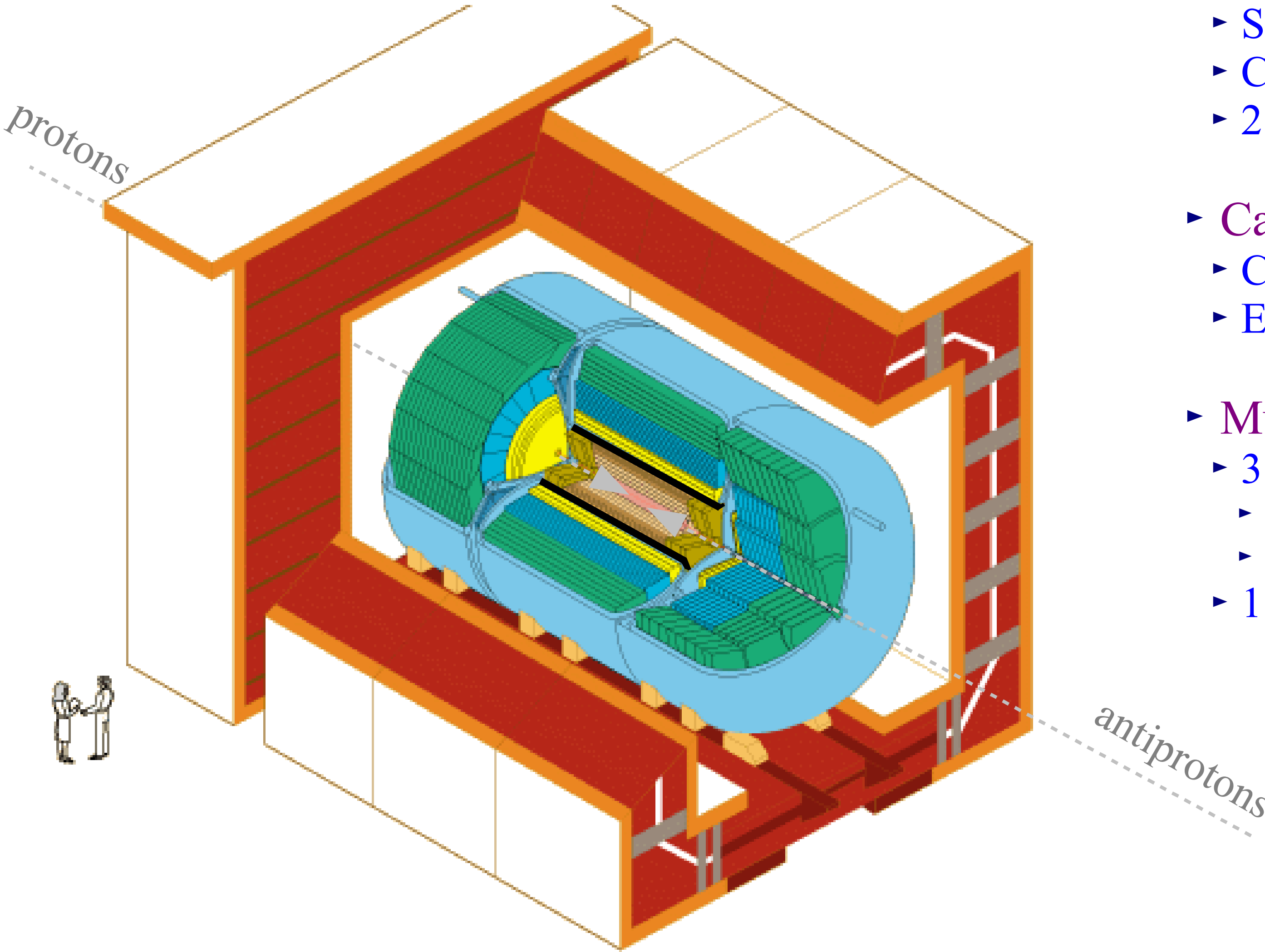
Conclusions

- DØ active in SUSY Higgs searches
  - Results with up to 7.3 fb^{-1} of data
  - Probing theoretically interesting regions
  - Combination of τ channels expected soon
- LHC experiments are moving very fast
  - Time to pass the baton

thank you


CMS Preliminary 2011 1.1 fb-1
tanβ
m_A [GeV]
95% CL excluded regions
CMS observed
±1σ theory
CMS expected
D0 7.3 fb-1
LEP
CMS 2010 observed
CMS 2010 expected
MSSM m_h^max scenario, M_SUSY = 1 TeV

DØ Detector



- Central Tracking System
  - Silicon Micro-strip Tracker
  - Central Fiber Tracker
  - 2 T Solenoid Magnet
- Calorimeters
  - Central Calorimeter (CC)
  - End Calorimeters (EC)
- Muon System
  - 3 sets of detectors
    - Scintillating tiles
    - Gas Drift Tubes
  - 1.8 T Toroid Magnets

Limit Setting

- Frequentist approach
  - If the experiment is repeated many times, what fraction would find a more extreme result?
    - Need to simulate repeating the experiment many times
      - Generate ensembles of pseudo-experiments allowing statistical and systematic fluctuations
      - Two hypotheses: Background only and Signal+Background
    - Need a test statistic
      - Poisson log-likelihood ratio:

$$LLR = -2\log\left(\frac{P(x\,;s+b)}{P(x\,;b)}\right)$$

x = observed number of events
s = predicted number of signal events
b = predicted number of background events

      - Systematic uncertainties mean that s and b are not exactly known
      - Fit systematics to observed data (or pseudo-experiment data) before calculating LLR
    - Now we can construct the LLR probability distribution for each hypothesis and see how they compare to the observed LLR

Limit Setting

- CL_{S+B} = probability of measuring a more background-like result when signal is actually present
- $1 - CL_B$ = probability of measuring a more signal-like result when there is actually no signal

- 95% CL limit
  - Could use CL_{S+B}
    - The cross section where $CL_{S+B} = 5\%$
    - But what if $1 - CL_B$ is also small?
      - The observed LLR is also inconsistent with the background only hypothesis!
  - Use $CL_S \equiv \dfrac{CL_{S+B}}{1 - CL_B}$
    - The cross section where $CL_S = 5\%$
    - Protects against setting limit too tight when the background is poorly modeled